DOCUMENT RESUME

ED 245 912 SE 044 645

TITLE	Studies of U.S. Universities' Research Equipment Needs Inconclusive.
INSTITUTION	General Accounting Office, Washington, D.C.
REPORT NO	GAO/RCED-84-105
PUB DATE	3 Apr 84
NOTE	25p.
AVAILABLE FROM	U.S. General Accounting Office, Document Handling and Information Services Facility, P.O. Box 6015, Gaithersburg, MD 20760.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*College Science; Engineering; *Equipment Evaluation; Higher Education; Instrumentation; *Laboratory Equipment; Mathematics; *Needs; Obsolescence; Research Design; Research Problems; *Research Reports; *Science Equipment; Sciences; Scientific Research; Universities

ABSTRACT

According to the General Accounting Office (GAO), scientific leaders estimated in 1982 that between $1 and $4 billion was necessary to update university research equipment. Because of this large cost variance, GAO was requested to assess how well past studies have defined the nationwide deficiency in university research equipment and to suggest what other work is needed to better determine equipment needs. GAO first identified 18 studies and then selected 5 completed and 2 on-going studies for closer scrutiny. Although the completed studies stated that universities have had a substantial need for equipment, none of these studies can be used to determine current needs for one or more of these reasons: the study focused on only one discipline; significant changes have occurred in the type and cost of equipment needed since the study was completed; the study's results could not be extrapolated to nationwide need; and the study is still in progress. One on-going study being conducted for the National Science Foundation by Westat, Inc. is discussed in detail since it may provide more thorough information than any study to date. However, it too may not provide the type of data necessary to determine the nationwide need for research equipment. (JN)

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REPORT BY THE U.S.

General Accounting Office

Studies Of U.S. Universities' Research Equipment Needs Inconclusive

In 1982, various scientific leaders estimated that the cost to update university research equipment was between $1 billion and $4 billion. Because of this large cost variance, GAO was requested to assess how well past studies have defined the nationwide deficiency in university research equipment and to suggest what other work is needed to better determine equipment needs.

GAO examined five completed studies that described the status of university equipment needs and two such studies which are still in progress. Although each completed study stated that universities have had a substantial need for equipment, none of these studies can be used to determine current needs.

When completed in 1985, the Westat study, funded by the National Science Foundation, is expected to provide more thorough information than any study to date. However, it may not provide the type of data necessary to determine the nationwide need for research equipment.

SE044045

GAO/RCED-84-105
April 3, 1984

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RESOURCES, COMMUNITY,
AND ECONOMIC DEVELOPMENT
DIVISION

B-214592

The Honorable Slade Gorton
Chairman, Subcommittee on Science,
Technology and Space
Committee on Commerce,
Science and Transportation
United States Senate

Dear Mr. Chairman:

The former chairman of your subcommittee requested that we (1) analyze studies and other relevant data to determine the causes and factors which influence universities' need for research equipment and (2) identify and evaluate options for equipping university laboratories. In May of 1982, your subcommittee held hearings on this topic, and we testified on the work we had accomplished up till then. In our testimony, we described several causes for the perceived need for research equipment but noted that available information was extremely limited. We stated that leaders of the scientific community estimated the cost of updating university research equipment to lie between $1 billion and $4 billion and that a more precise estimate did not exist.

Because of this large cost variance, your office requested on June 21, 1982, that our further efforts address the following objectives:

--assess how well past studies define the deficiency[1] in university research equipment and

--suggest what other work may be done to get a better grasp of the magnitude and urgency of the deficiency in university research equipment.

SCOPE AND METHODOLOGY

We performed an extensive literature search and interviewed about 200 individuals at federal agencies, universities, and

[1]Deficiency includes shortages in amount and type of equipment, obsolescence, and the absence of state-of-the-art equipment.

private organizations.[2] Our review resulted in the identification of 18 studies (see app. II) which addressed university research equipment. Of the 18 studies, we selected 7 (5 completed and 2 ongoing) which we believe best describe the status of university equipment needs. We used the following criteria to select the 7 studies:

--The study's principal focus had to be on equipment needs for research and graduate education.

--The study had to deal with equipment costing between $1,000 and $1 million. We did not include major facilities such as high-energy particle accelerators and telescopes. (Because of their size and cost, major facilities are usually planned and budgeted individually. Thus, the need for major facilities is normally assessed and debated separately from the broader overall issue of research equipment needs.)

--The study had to use a methodology with particular relevance to determining university equipment needs.

--The study was frequently mentioned in literature we reviewed and in interviews we held.

We analyzed these studies to determine (1) if they could estimate the current magnitude of research equipment needs and (2) the best methodology to assess research equipment needs. We sent early drafts of our analysis of each of the seven selected studies to the respective authors for their comments. Additionally, we had an early draft of this report reviewed by three senior individuals from the scientific community. The comments of the authors and report reviewers have been addressed in this report.

We also obtained information on a Department of Defense (DOD) 5-year, $150-million university research equipment program which began in fiscal year 1983. We interviewed officials from the Office of Naval Research responsible for coordinating the DOD program.

Our review was conducted in accordance with generally accepted government auditing standards.

THE SEVEN STUDIES EXAMINED CANNOT BE USED TO DETERMINE CURRENT NEEDS

None of the seven studies we reviewed can provide a current estimate of the magnitude of the nationwide research equipment

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[2]See appendix I for a list of organizations we visited.

needs for one or more of the following reasons: (1) the scope of the study was limited in that it focused on one discipline (i.e., chemistry), (2) significant changes have occurred in the cost and type of equipment needed since the studies were completed, (3) the methodology did not permit the extrapolation of study results to the nationwide need because the study was not based on a representative sample of universities or was not supported by empirical evidence, and (4) the study is currently in process. All of the five completed studies, however, concluded that the universities' need for research equipment was significant and of major concern to the scientific community.

Of the seven studies analyzed, we found that one, currently in process (the Westat study), presents the best opportunity for assessing current research equipment needs. Another (a 1971 National Academy of Sciences study) used the best methodology for assessing equipment needs in that it used

--a representative sample of universities and

--a panel of science experts (peer reviewers) to review and validate the universities' stated needs for research equipment.

The Westat study is discussed briefly below and in more detail in appendix III. The 1971 National Academy of Sciences' study is discussed in appendix IV.

The Westat study

Public Law 96-44, dated August 2, 1979, mandated the National Science Foundation (NSF) to develop research equipment indicators (i.e., stock, age, cost, and needs). Subsequently, NSF contracted with Westat, Inc., to develop such indicators. Westat plans to develop indicators for the following disciplines--engineering and the physical, computer, biological, agricultural, and environmental sciences. The study will collect baseline data covering the age, stock, cost, maintenance, and repair rate of research equipment in a sample of university departments. The study will also collect information from each university department head on what three pieces of equipment, presently not available, would have the greatest value to the research in his/her department.

Although the Westat study is expected to provide more thorough information than any study to date, restricting the response to three pieces of new equipment and depending solely on the department chairperson's perspectives may not provide the measure of data necessary to determine the nationwide need for research equipment. (See app. III, p. 9.) The Westat study is scheduled for completion in 1985.

DOD PROGRAM DATA COULD HELP GET A BETTER GRASP OF EQUIPMENT NEEDS

A partial estimate of university equipment needs could be obtained from DOD's university research equipment program. In fiscal year 1983, DOD began a special 5-year university research equipment program totalling $150 million. The solicitation for the first year of the program requested proposals specifically to purchase additional equipment in a broad range of scientific disciplines of interest to DOD. (For a list of disciplines, see app. V.) Academic researchers, including those not presently supported by DOD, were encouraged to submit proposals.

DOD received about 2,500 proposals requesting a total of about $645 million worth of research equipment. DOD has funded $30 million of the best proposals selected by the staffs of the research offices of the Army, Air Force, and Navy. However, many of the remaining proposals also may contain valid needs. Although it is limited to scientific fields in the DOD solicitation and will exclude that segment of the scientific community that does not receive or seek military support, we believe these data could be used as an initial step in obtaining a partial estimate of research equipment needs for the fields covered.

FUTURE EQUIPMENT STUDIES SHOULD INCORPORATE A REPRESENTATIVE SAMPLE OF UNIVERSITIES AND USE PEER REVIEW

If any future work is done to assess research equipment needs on a broader basis, we believe it should incorporate a methodology which assesses a representative sample of universities and includes a peer review process designed to validate identified equipment needs similar to that used in the 1971 National Academy of Sciences study. (See app. IV.)

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As agreed with your office, we plan no further distribution of this report until 30 days after its issuance, unless you release its contents earlier. At that time, we will send copies to other congressional committees; the National Science Foundation; the Office of Science and Technology Policy; and the Director, Office of Management and Budget. We will also make copies available to other interested parties upon request.

Sincerely yours,

Ralph Carlone for

J. Dexter Peach
Director

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ABBREVIATIONS

C^3	command, control and communications
DNA	deoxyribonucleic acid
DOD	Department of Defense
EM	electromagnetic
FY	fiscal year
GAO	General Accounting Office
NAS	National Academy of Sciences
NIH	National Institutes of Health
NSF	National Science Foundation
UV	ultraviolet

ORGANIZATIONS AT WHICH WE CONDUCTED INTERVIEWS

UNIVERSITIES

Auburn University, Auburn, Ala.

Florida State University, Tallahassee, Fla.

Georgia Institute of Technology, Atlanta, Ga.

Harvard University, Cambridge, Mass.

Massachusetts Institute of Technology, Cambridge, Mass.

University of Maryland, College Park, Md.

University of Michigan, Ann Arbor, Mich.

University of Texas, Austin, Tex.

PRIVATE SECTOR ORGANIZATIONS

Du Pont.

Geophysical Laboratory, Carnegie Institution.

Litton Bionetics.

Scientific Apparatus Makers Association.

GOVERNMENT AGENCIES

National Engineering Laboratory, National Bureau of Standards.

National Science Foundation.

Office of Naval Research.

Office of Science and Technology Policy.

National Institutes of Health.

APPENDIX II

LIST OF RESEARCH EQUIPMENT STUDIES

We identified the following studies as particularly descriptive of the state of university research equipment. They are listed alphabetically by title. (Asterisks mark those studies which we selected for detailed examination.)

COMPLETED STUDIES

* An Assessment of the Needs for Equipment, Instrumentation, and Facilities for University Research in Science and Engineering. National Academy of Sciences, September 1971.

This study evaluates the equipment needs of research universities as indicated by a sample of eight science and engineering departments in each of 10 major disciplines. This was the first study to document the deteriorating research equipment situation across the major fields of science in the "post-Sputnik" era. It called for an ongoing effort to monitor and assess instrumentation needs in all major science and engineering disciplines.

* Chemistry: Opportunity and Needs. National Academy of Sciences, National Research Council, Washington, D.C., 1965.

This study is one of the series of discipline-oriented assessments sponsored by the National Academy of Sciences (NAS) from the mid-1960's through the early 1970's. Equipment is one of many issues studied that is related to chemistry. The study looks at the history and uses of equipment for basic research, and examines the cost and financing of equipment. It estimates the national deficiency in equipment in university chemistry departments.

A Crisis in Engineering in Texas. The Texas Society of Professional Engineers, 1982.

The study lists the most urgently needed equipment for engineering in 10 Texas colleges and universities.

Equipment Needs and Utilization. Final Report to the National Science Foundation Advisory Council, 1978.

This study was done by Task Group No. 5 of the National Science Foundation (NSF) Advisory Council. The objective (task) of the group was

> ". . . to discuss and document research equipment needs within the university environment, and the role of federal funding in alleviating these needs. Included would be the replacement of obsolete equipment and acquisition of additional equipment and related facilities."

This study contains a comprehensive set of findings and recommendations.

Expenditures for Scientific Research Equipment at Ph.D. Granting Institutions, FY 1978. Irene L. Gomberg and Frank J. Atelsek. Higher Education Panel Report, Number 47, American Council on Education, March 1980.

The American Council on Education, through its Higher Education Panel, studied the university equipment situation for NSF. The study collected information for fiscal year 1978 on the level of institutional expenditures for research equipment, the federal contribution to those expenditures, and the share of the funds spent on high-cost items. This is the only study that attempted to collect data on expenditure for equipment by all disciplines.

Extramural Instrumentation Funding by the National Institutes of Health. Prepared by Dr. Kirt J. Veneer, April 1981.

The purpose of this report was ". . . to retrospectively view and comment on . . . requests made as part of regular research grants as they moved through the review process prior to funding." Three types of data were reviewed: evidence put forward to substantiate obsolescence claims; the funding of equipment by all Bureaus, Institutes, and Divisions in the National Institutes of Health (NIH); and the pattern of funding for two NIH institutes. This study provides a unique description of the extent to which a single federal agency contributes to the funding of research instrumentation as a part of project-oriented research programs.

The Life Sciences. Committee on Research in the Life Sciences and Public Policy, National Academy of Sciences, Washington, D.C., 1970.

Like the previously mentioned study on chemistry, this was also one of several discipline-oriented studies sponsored by NAS. Equipment is one of several dimensions of life sciences that is examined. Equipment is examined as a tool of biological research and as a requirement ". . . for the future of the academic endeavor in the life sciences." Separate questionnaires were used to collect data from individual academic scientists and from department chairpersons.

* The Nation's Deteriorating University Research Facilities: A Survey of Recent Expenditures and Projected Needs in Fifteen Universities. Prepared for the Committee on Science and Research of the Association of American Universities, Washington, D.C., 1981.

This study is a companion to the 1980 Association of American Universities report on instrumentation needs (listed

below). It was a preliminary investigation into some of the unanswered questions raised by earlier studies concerning major research equipment and facilities. Expenditures for the last 4 years (1978-81) and anticipated spending for 3 years (1982-84) were collected from 15 universities for new construction, facility modernization, major repair and renovation, and special research equipment. The sources of funds were not identified in the data.

* Report of the Ad Hoc Committee on the Status of Geochemical/Mineralogical Instrumentation. National Research Council's Geological Sciences Board, 1982.

This study, based on replies from department chairpersons of 65 universities, examines the crisis in geochemical equipment.

Research Equipment Assistance Program: A National Science Foundation Research Management Improvement Project Research Report. Volume I--Basic Report; Volume II--REAP Office Procedure Guide; Volume III--Computer Support user Manual; Volume IV--Implementing an Equipment Assistance Program. Iowa State University, October 1976.

The objective of the study was

> ". . . to describe a cost effective rapid response system for assisting faculty researchers and teachers with scientific equipment-related needs through sharing, loans, and transfers. Faculty cooperation in sharing was achieved through a voluntary system independent of property accounting."

This program forms a model for other universities to copy in their effort to meet federal requirements for equipment sharing.

* The Scientific Instrumentation Needs of Research Universities. A Report to the National Science Foundation by the Association of American Universities, June 1980.

The principal objectives of this study were ". . . to assess the current status of instrumentation in the major research universities and to identify factors which either facilitate or impede its development, acquisition, use and maintenance." Estimates were made ". . . of the future consequences of current instrumentation funding policies on the capacity of the research universities to conduct productive research."

Shared Use of Scientific Equipment at Colleges and Universities, Fall 1978. Frank J. Atelsek and Irene L. Gomberg. Higher Education Panel Report, Number 44, American Council on Education, November 1979.

APPENDIX II

This survey ". . . gathered information about the kinds of formal and informal procedures colleges and universities follow to facilitate sharing of scientific equipment . . . . The methods of sharing range from small-scale cooperative arrangements between departments to sophisticated institutional-wide computer maintained systems." This is the only study to systematically collect data on the shared use of scientific equipment at colleges and universities.

The Snowbird Report--A Discipline in Crisis. Computer Science Board (1980 Biennial Meeting). Communications of Associations for Computing Machinery, Volume 24, Number 6, 1981.

This report was developed during the 1980 biennial meeting of Computer Science department chairpersons. It is the result of intensive discussions about the crisis in computer science. Brief mention is made of the need for ". . . computing facilities capable of sustaining experimental research." An appendix to this report shows the levels of capital investment per researcher required for different standards of research facilities.

The State of Academic Science: The Universities in the Nation's Research Effort. Bruce L.R. Smith and Joseph J. Karlesky. New York, Change Magazine Press, 1977.

This study examined the universities' role in the nation's research and development effort. It discusses instrumentation needs as one of several emerging issues in academic research. It identified "the deterioration of instrumentation and other supporting resources for academic research" as one of four factors that was causing "uncertainty and anxiety" about the continued strength and vigor of the academic science enterprise in the United States.

A Study to Improve the Management of Costly Instrument Centers. A Report to the National Science Foundation by the Department of Chemistry, University of Utah, 1975.

In this study, the authors ". . . examined the distribution of major instruments and the various forms of management practices involved in instrumental support of chemical research which have evolved in the U.S. and selected foreign countries." The authors also attempted ". . . to assess operating costs of instrumental services under varying circumstances." Information on both the research equipment situation in Europe and on the operations and needs of chemical equipment centers are unique contributions to the understanding of the situation.

ONGOING STUDIES

* A study of equipment needs in North Carolina by the North Carolina Board of Science and Technology

This is a survey of the entire universe of laboratories within the state. It utilizes peer review and defines need not only on the basis of what should be purchased, but on what can be shared.

* The nation-wide study of university research equipment by Westat, Inc., performed for the National Science Foundation

This study is currently being undertaken by Westat Inc., under contract to NSF. Its objective is to develop statistically reliable indicators of need for major research instruments. This 3-year study will survey 43 universities and colleges and is scheduled to be completed in 1985.

Ongoing study by the American Chemical Society

This study is designed to take inventory of the equipment available in the labs and determine what the perceived needs will be over the next 2 to 5 years. The survey was begun in spring 1982.

THE WESTAT STUDY

OBJECTIVES, SCOPE, AND METHODOLOGY

The most extensive study of university research equipment is presently being undertaken by Westat, Inc., under contract to NSF. The official project statement by NSF states that the study's objective is:

> ". . . to develop statistically reliable indicators of current national status of need for major research instruments in higher educational institutions, and of recent trends in the stock, cost, condition, obsolescence and utilization of such instrumentation."

This project began with a feasibility study designed to test whether universities would be able to provide the data desired by NSF. Additionally, Westat wished to learn how to collect the information from the universities while minimizing the burden of its questionnaire. The feasibility study was completed in spring 1982. It used a stratified sample of 38 institutions selected from the 400 colleges and universities with research and development expenditures of at least $250,000 in any years from 1976-79. Questionnaires were sent to university department chairpersons, principal investigators, and financial officers/administrators asking for data on the following disciplines: cell biology, organic chemistry, solid state physics, and electrical engineering.

According to both NSF and Westat, the results of the feasibility study were promising. The universities were able to provide the requisite data. Westat was able to design an approach to data collection for the main study, which is expected to cause the least amount of burden to the universities. NSF elected to summarize the data from this feasibility study in an issue of Highlights (NSF 82-316) published on June 14, 1982.[1] This document contained data from the sample institutions on age and stock of equipment according to initial price, distribution of equipment according to number of users and initial cost, and downtime attributed to equipment failure, by cost.

Westat received the contract in September 1982 to begin the major data collection effort. It is a two-phase project, with phase I focusing on the physical sciences, computer sciences, and engineering. Phase II began in 1983 and covers the biological, agricultural, and environmental sciences. The 3-year study will collect data from a sample of 43 universities and colleges

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[1] Highlights is a newsletter occasionally published by NSF to give an overview of current data on science and technology.

selected from the approximately 160 academic institutions with over $3 million worth of annual research and development expenditures in any of the years 1977-80.[2]

TYPE OF DATA TO BE COLLECTED BY WESTAT

Westat will develop indicators on the basis of data collected from two sources: data on research equipment from each institution from central record files (such as those maintained by property management offices) and department chairpersons. The first category pertains to inventory, costs, usage, and maintenance. The second requests the opinion of the department chairpersons on various aspects of equipment use and need.

The first category of information starts with a detailed inventory of research equipment in place in each surveyed department, then for each piece of equipment costing over $10,000, information will be requested on:

--year acquired;

--initial and replacement costs for the item and its present dedicated accessories;

--how acquired (donated, purchased, locally assembled, etc.);

--if purchased, sources of funding (percentage from specific federal or non-federal sources);

--who uses the item (how many researchers, from which departments or institutions);

--function of the item (whether it is back-up or primary);

--technical capabilities of instrument and of its accessories (whether it is state of the art, used for research, or not used for research in 1982); and

--operating condition of the item.

The department chairpersons will be asked for information on their departmental size, percentage of expenditures on research equipment (by source), facilities for maintaining and designing instrumentation, and how the department budgets for maintenance. This category will pertain to the department chairpersons' assessment

[2]The total number of academic institutions annually spending over $3 million was verified as 1981 data became available.

of need for research equipment, as requested by the following types of questions:[3]

--In what price category is equipment most needed?

--What three pieces of equipment, presently not available, would have the greatest value to the research in the particular department?

--What is the relative priority of need for increased instrumentation funding, compared with other departmental needs--such as support for graduate students or professional support?

--Is the quality of research or education hindered or limited by the type and age of existing research equipment?

--Have non-federal funding sources or alternative financial arrangements been explored or used by the department?

GAO COMMENT

The Westat study will provide more thorough information than any other study to date. This effort assesses need for equipment in several ways. It requests department chairpersons to give an overall assessment of equipment in their departments. This departmental assessment is to include consideration of what research cannot be done as a result of present equipment. Then, the questionnaire asks the departments to list the three new pieces of equipment most needed. Department chairpersons also are asked, if they had a constant level of funding, whether they would recommend any redistribution of funds between (1) support for purchase and maintenance of research equipment and (2) various categories of support for personnel (such as graduate students, post doctorates, etc.). Finally, department chairpersons are requested to offer suggestions on how federal equipment policies and/or procedures could be modified to better meet the research needs of researchers in their respective departments. Taken together, this information will provide valuable insight into the assessment of need, through the eyes of department chairpersons.

However, the study may not provide all of the information necessary to determine how much research equipment is needed nationwide because: (1) restricting the response to three items may not be adequate for larger departments, particularly those with research in a variety of expanding subfields, (2) the responses

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[3]For purposes of brevity, we do not directly quote questions or provide the entire detailed list which will be used by Westat. Our summary of questions is intended to demonstrate the kind of information which will be collected.

from department chairpersons may not be representative of the perspectives of researchers in their departments, and (3) the responses will not be subjected to a peer-review process to render second opinions as to whether the research equipment is needed.

THE NATIONAL ACADEMY OF SCIENCES' 1971 REPORT ON RESEARCH EQUIPMENT

OBJECTIVES, SCOPE, AND METHODOLOGY

In 1971, NAS assisted NSF with a survey, the major goal of which was to assess equipment needs at a sample of universities. It was entitled An Assessment of the Needs for Equipment, Instrumentation, and Facilities for University Research in Science and Engineering. The objectives of the study were to collect data on the types of major equipment needed to conduct an effective program of research at a sample of major university departments, and to evaluate these equipment needs in relation to the total department budget, sources of support (federal, state, private sector), size and capability of the research staff, and critical significance to the research for which it would be employed.

Data were collected by surveying eight university departments in each of 10 disciplines[1] for a total sample of 80 university departments.[2] Departments were requested to list equipment need, defined according to two criteria: the equipment could be used for research during the 1971-72 academic year, and no additional staff would be required to operate any new equipment. Following the survey, NAS selected teams of scientists and engineers from outside the surveyed departments to determine the validity of equipment needs by conducting site visits. Through the scrutiny of these experts, cuts of from 5 to 40 percent were made to the departments' lists of their equipment needs.

FINDINGS

The study concluded that equipment needs indicated by the various departments were, for the most part, valid--"a pressing need for equipment in the $100,000 - $300,000 price range" existed in university science and engineering centers to support

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[1]They were: plant and animal physiology, biochemistry/molecular biology, psychology, developmental biology, chemistry, physics, geology, chemical engineering, electrical engineering, and mechanical engineering.

[2]For each of the 10 disciplines, NAS selected its sample of eight departments from "A Rating of Graduate Programs," which was conducted by the American Council on Education in 1970. The selection was weighted to include a greater number of higher ranked departments.

existing research. The findings were presented for each discipline in terms of estimates of total nationwide and average departmental need as ranked by size by the American Council of Education.

The study additionally stated briefly that the maintenance of existing equipment was also a problem, in that the evaluation found ". . . no consistent policy for the provision of funds for maintenance . . . among the institutions studied." This could be troublesome, since ". . . annual maintenance costs can amount to as much as ten percent of the initial cost of a piece of equipment."

GAO COMMENT

We believe that this study used the best methodology for estimating the nationwide university research equipment needs. More specifically, data were collected from a well-represented sample and subjected to peer review.

SCIENTIFIC AREAS OF INTEREST AS LISTED IN DOD-UNIVERSITY RESEARCH INSTRUMENTATION PROGRAM, FISCAL YEAR 1983

PHYSICAL AND MATHEMATICAL SCIENCES

Rydberg state atoms
Lasers
Physics of particle beams
Detection physics
Pulsed power research
Free electron lasers
Physical acoustics
Rapid heating and cooling
Optics
Physics of space prime power
Detonation physics
Nonlinear optics
Extreme UV and soft X-ray generation, spectroscopy
Plasma and ion physics
Physics of discharges
Precision timing
Collective electromagnetic effects

Synthetic chemistry
Liquids
Materials processing
Detection and identification of transient species
Surface chemistry
Piezoelectric polymers
Conducting polymers
Emulsions and micellar catalysis
Inorganic polymers and fluids
Chemistry of electronic materials
Photochemistry
Molecular dynamics
Structural polymer research
Chemiluminescence
Primary battery research
Secondary battery research
Solid state chemistry
Solid electrolyte materials
Physical chemistry
High-temperature chemistry
Analytical chemistry
High-energy chemical lasers
Bulk polymer diffusion studies
Upper atmosphere chemistry
Mathematical statistics and
applied probability

Computational statistics and
modern data analysis
Statistical signal processing
and related computer architectures
Reliability and quality assurance
Stochastic processes and
time series analysis
Image and related multidimensional
signal processing
Simulation methodology
Mathematical and statistical aspects
of remote sensing
Statistical methods in target tracking

Differential and integral equations
Numerical solution of partial
differential equations
Large-scale scientific computing
Engineering optimization
Special purpose digital devices
Large-scale systems
Organization and game theory
Fast algorithms
Control theory
Analysis of nonlinear reaction-
diffusion systems
Combinatorics and complexity

Superconducting devices and materials
Spread spectrum communications
Protocols for computer
communications networks
Communications theory
Robust statistical methods
Optical processing innovations
Near millimeter waves
Generation, detection,
control electromagnetic waves
Light-induced processes at semiconductor/
liquid interfaces
Surface science
Ultra-small electronic devices
Solid-state surfaces and interfaces
Synthesis and analysis of EM materials
Signal processing (optical and non-optical)
Microwave devices and millimeter wave devices
Large-scale integrated circuit design
and simulation
Materials for ultra-small electronics
Cryoelectronics
Picosecond opto-electronics
Mutilayer electronic materials
Semiconductor devices and materials
for hostile environments

Electromagnetic scattering cross-sections
Cryogenics and refrigeration
Atmospheric limitations on electro-optical and near-millimeter wave propagation
Nonlinear ionospheric processes

ENGINEERING SCIENCES

Advanced Ti alloys
High-strength ferrous metallurgy
High-performance Al alloys
Advanced superalloys
Mechanical properties of metals
Tribology
Critical materials
Adhesion science
Composites
Nondestructive evaluation
Processing science
Welding
Rapid solidification technology
Tough Ceramics
Transducer and sensor materials
Solid dielectrics
Optical materials
Armor materials
Environmental degradation
Protective coatings
Environmentally assisted fracture
Oxidation and corrosion of turbine materials
Aqueous corrosion
Fatigue and fracture mechanics

Ship hydrodynamics
Aeromechanics
Geophysical fluid mechanics
Turbulence
Computational mechanics
Compliant coatings
Structural and hydro acoustics
Structure/fluid interaction
Structural mechanics
Energetic materials
Reactive fluid mechanics and combustion
Turbomachinery
Aeropropulsion
Marine propulsion
Heat transfer
Precision engineering

Vertical lift
Electromagnetic propulsion
Software engineering
Distributed computing systems
Computer graphics
Artifical intelligence
Robotics
Manufacturing science
Expert systems
Man-machine interfacing
Digital communications
Very large-scale integrated circuit design and simulation
Office automation

ENVIRONMENTAL SCIENCES

Physical, chemical, biological, and coastal oceanography
Remote sensing
Marine meteorology and atmospheric sciences
Marine geology and geophysics
Underwater acoustics
Arctic science
Marginal ice zone
Deep submersible research
Ocean science engineering
Benthic boundary layer processes
Ocean acoustic tomography
Military hydrology
Solar terrestrial relations
Deep-space surveillance
Environmental effects on C^3, guidance and surveillance
Upper atmosphere
Geodetic-measuring techniques

LIFE SCIENCES

Adaptation in organizations
Intergroup relations
Turnover and retention
Theory-based personnel assessment
Human information processing abilities
Instructional theory and advanced training systems
Cognitive processing
Man-machine system interfaces
Visual and auditory perception
Information processing and decision making

APPENDIX V

Pest control on stored products
Stress physiology
Blood components for long-term storage
Predictive toxicology
Electrically mediated cell growth
Bio-effects of toxic hazards and EM radiation
Impact, flail, vibration effects
Immunological defense against unidentified sources
Microbiology/recombinant DNA
Defense against chemical and biological agents
Biomaterials

Source: Office of Naval Research, DOD-University Research Instrumentation Program, FY 1983, pp. 4-7.

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